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DoD PROFIT POLICY AND CAPITAL INVESTMENT IN THE MILITARY AIRCRAFT INDUSTRY

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March 1990

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The purpose of this research was to conduct an economic analysis of a selected set of contractors in the military aircraft manufacturing industry. Specifically, two questions were addressed: (1) Are changes in the progress payment rate inversely related to changes in the firms' capital/labor ratios? and (2) Has the DoD profit policy succeeded in promoting investment in capital facilities and equipment? These questions were tested statistically using time-series data. We found no evidence that the progress payment rate was inversely related to changes in the capital/labor ratio. As for the facilities capital markup, we found that the markup rate seems to promote investment in capital facilities and equipment.

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PREFACE

This paper was prepared by the Institute for Defense Analyses (IDA) for the Office of the Assistant Secretary of Defense, Program Analysis and Evaluation (OASD(PA&E)), under Contract MDA 903 89 C 0003, Task Order T-Q7-665, issued January 24, 1989. The objective of the task was to conduct an economic analysis of a selected set of contractors in the military aircraft manufacturing industry.

Mr. Howard J. Manetti served as the cognizant technical official for the task until his retirement in December 1989. Mr. Gary Bliss has been the technical official since then. This paper has been reviewed within IDA by Mr. Stanley Horowitz and Dr. David R. Graham. Dr. Thomas R. Gulledge, Jr., one of the authors of this paper, was a consultant to IDA for this study.

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TABLES

I. INTRODUCTION

Prior to 1976, Department of Defense (DoD) policy was to reimburse its contractors for depreciation, but not for any of the other explicit or opportunity costs of holding capital equipment. However, an internal DoD study indicated that, in 1975, the ratio of facilities capital to sales was only 9 percent for manufacturing firms in the defense industry, but 20 percent for a control sample of durable-goods manufacturers in the commercial sector.[1]

The relatively low degree of capital investment led to several concerns within DoD. First, there was concern that antiquated capital equipment might be a symptom of inefficient production techniques. Second, some officials believed that the defense industry lacked the excess capacity that would be required to meet surge production levels in the event of war.

To allay these concerns and encourage capital investment, two new components of markup above cost were established in 1977. First, the facilities capital cost of money is computed as the product of an interest rate and the net book value of the contractor's capital stock. This component is intended to compensate the contractor for the opportunity cost of holding capital. The same interest rate is applied, without regard to whether the contractor's source of funds is equity or borrowed capital.

Second, the contractor also receives the facilities capital markup. This component is computed as the product of a markup rate and the net book value of the capital stock. The current markup rates are given by the ranges 10 to 20 percent per year for buildings, and 20 to 50 percent per year for equipment. The facilities capital markup compensates the contractor for the loss of liquidity when investing in physical rather than financial assets.

As long as the facilities capital cost of money tracks with market interest rates, its nominal variation should have no effect on the contractor's incentive to invest. However, the facilities capital markup rate has increased monotonically over the years, being non-existent prior to 1977 and being quite generous at present. The first objective of this paper

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1 The source of these statistics is the so-called Profit '76 Study [4]. These statistics were updated in a later DoD study, the Defense Financial and Investment Review (DFAIR) [5]. In these studies, facilities capital is defined as the remaining (after depreciation) or net book value of tangible and intangible assets subject to amortization, and assigned to defense-related operating segments or divisions. The statistics for both sectors exclude shipbuilding, for which the technology was not judged comparable.

is to test whether the increase in the markup rate has been translated into a corresponding increase in the degree of capital investment among defense contractors.

The facilities capital markup is cumulated over the duration of a manufacturing contract, and is paid to the contractor at final delivery. By contrast, the majority of expenditures on labor and materials are reimbursed at regular intervals (usually monthly) via progress payments. The percentage of costs that are reimbursed early is called the progress payment rate; the remaining costs are reimbursed at final delivery.

An increase in the progress payment rate leads to "faster" reimbursement of expenditures on labor and materials. The facilities capital markup is still paid at final delivery, however, so that the effective rate on that factor remains at zero. Therefore, an increase in the progress payment rate should provide an incentive for the contractor to substitute labor and materials for capital in production. The second objective of this paper is to test whether historical variations in the progress payment rate have had the predicted effect on the degree of capital investment.

Section II of this paper provides a more detailed discussion of the policies by which DoD reimburses manufacturing contractors. Section III develops specific hypotheses regarding the facilities capital markup rate and the progress payment rate. Section IV describes the data used to test these hypotheses, and Section V reports the results of these tests. Finally, Section VI contains our conclusions.

II. OVERVIEW OF DOD PROFIT POLICY

DoD profit policy is a collection of regulations that are applied to major contracts[2] to ensure that the profits on these contracts are "fair and reasonable." Profit policy is promulgated in the Federal Acquisition Regulations (FAR) [6], published in 1984, and in subsequent amendments. This section provides only a brief synopsis of the FAR; more detailed expositions are available in Osband [13] and Rogerson [15].

In DoD parlance, "profit" is defined as payment to the contractor in excess of allowable costs. Profit, so defined, need not equal the contractor's net income, because DoD policy prohibits reimbursement of certain cost elements (e.g., explicit reimbursement of interest expense).

Profit is negotiated in advance of production, on the basis of anticipated costs. As we will see, profit is roughly equal to a percentage of allowable cost, plus a factor that is proportional to the value of capital employed in contract performance. It is important to distinguish this *ex ante* profit from the *ex post* profit that results if actual costs differ from anticipated costs. During contract negotiation, the contractor and DoD agree on a sharing ratio, s, such that the contractor pays 100s percent of any cost overrun and DoD pays the remaining 100(1 - s) percent. The sharing ratio is at least 0.0 and at most 1.0. In the best case (from the contractor's viewpoint), s = 0.0 and the contractor is indifferent to cost overruns.

Because negative values of s are expressly prohibited,[3] the contractor's profits are never increased by a cost overrun. A contractor's *ex ante* profits may increase by bidding a higher level of anticipated costs (provided the contractor still wins the contract award), because *ex ante* profits are, in part, proportional to anticipated costs. However, the contractor's *ex post* profits never increase if actual costs exceed anticipated costs. In fact, these profits decrease if s > 0.0.

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2 In this paper, a major contract is one that exceeds six months in duration and one million dollars in contract value. Major contracts represent a minority in numbers of DoD contracts, but they account for the vast majority of contract dollars.

3 See 10 *United States Code* 2306(a) and 41 *United States Code* 254(a).

A. WEIGHTED GUIDELINES

The professed motives for offering profit margins above allowable costs are: (1) to stimulate efficient contract performance, (2) to attract the best capabilities of qualified large and small business concerns to government contracts, and (3) to maintain a viable industrial base ([6], section 15.901).

Profit margins are determined by a set of rules known as the weighted guidelines. The upper portion of Table 1 summarizes the weighted guidelines. The first column of the table simply names the various components of profit. The DoD contracting officer selects a profit rate for each component, which must lie between the lower and upper limits indicated in Table 1. The table also indicates the "normal" profit rate, which is just the midpoint of the lower and upper limits. If, for example, the contracting officer determines that the project contains an unusual amount of technical risk, then he is empowered to offer the upper limit of a 1.8-percent markup on this component. The profit rate selected is then applied to the base indicated in the final column of the table. The cost-based components are proportional to total allowable costs minus General and Administrative (G&A) costs.

Table 1. Profit Policy as of 1987

	Allowable Range			
Component of Profit	Low	Normal	High	Base to Which Applied
Technical Risk	0.6%	1.2%	1.8%	Total Cost - G&A
Management Complexity	0.6%	1.2%	1.8%	Total Cost - G&A
Cost Control	0.8%	1.6%	2.4%	Total Cost - G&A
Contract Risk				
Firm-Fixed-Price	2.0%	3.0%	4.0%	Total Cost - G&A
Fixed-Price Incentive	0.0%	1.0%	2.0%	Total Cost - G&A
Facilities Capital Cost of Money		5-year Treasury Rate[a]		Net Book Value
Facilities Capital Markup				
Land	0.0%	0.0%	0.0%	Land Value
Buildings	10.0%	15.0%	20.0%	Building Value
Equipment	20.0%	35.0%	50.0%	Equipment Value
Working Capital Adjustment		5-year Treasury Rate[a]		Complex Formula

[a]This percentage is constant; ranges do not apply.

In practice, the DoD contracting officer and the contractor negotiate over the total profit rate, not the individual components of profit. This practice is condoned by the FAR regulations: "Specific agreement on the exact values or weights assigned to individual profit-analysis factors is not required during negotiations and *should not be attempted.*" ([6], section 15.807) [Emphasis added.]

Our analysis ignored the cost-based components of profit, concentrating instead on the components related to facilities and working capital. This decision was made for three reasons. First, there has historically been little variation in the profit rates assigned to the cost-based components. A study by the Logistics Management Institute [12] analyzed profit margins on 3,686 manufacturing contracts negotiated over the period 1980-1982. The markup rate on cost (i.e., the sum of the cost-based components of profit, divided by contract cost) had a sample mean of 11.5 percent and a standard deviation of only 2.9 percent. Hence, there was little variation in the markup rate on cost, either across contracts or across the three years studied.

Second, there is little reason to believe that the markup rate on cost, even if it had changed, would have affected the mix of inputs (capital, labor, and materials) selected by the contractors. All allowable costs receive the same markup; hence, the markup provides no particular incentive for the contractor to employ one input versus another in production.

Finally, unlike the cost-based components of profit, the capital-based components have been used over the years by DoD to influence the degree of capital investment among DoD contractors. Indeed, the major focus of our research was to determine whether these incentives have had the desired effect.

B. PROFIT COMPONENTS RELATED TO FACILITIES CAPITAL

DoD policy has always been to disallow reimbursement of interest expenses. According to Osband ([13], p. 15):

> Ever since the first set of formal cost principles was issued in 1940, the Government has explicitly disallowed interest charges. That is, not only is no markup calculated on interest costs, but the very interest itself is not reimbursed. It accrues as a wasteful expense, to be subtracted from the nominal calculated profit. Government justifications for not allowing interest include discouragement of excessive debt financing, avoidance of disputes over appropriate financing costs, and neutralization of special competitive advantages of cash-rich big businesses [sic].

Although DoD does not allow interest as a reimbursable cost, it has since 1977 allowed interest charges in the computation of "profit." While the DoD accounting definitions of "cost" and "profit" differ from those advanced by economists, the end result is that DoD contractors are compensated quite generously for the costs of capital ownership.

The final three components of Table 1 indicate the components of profit that are related to facilities capital. The facilities capital cost of money and the facilities capital markup were both introduced in 1977. In each case, the net book value of capital employed in production is multiplied by a markup rate, and the result is summed for each year of project duration. This procedure is applied without regard to whether the contractor's source of funds is equity or borrowed capital.

Rogerson ([15], p. 2.8) shows that the treasury rate,[4] used to compute the facilities capital cost of money, is generally one percentage point higher than the imputed interest rate on U.S. government bonds with a maturity of five years. The extra percentage point is presumably a risk premium, reflecting the fact that corporations borrow at a higher interest rate than does the government. The facilities capital markup is an additional component of profit, presumably compensating for the loss of liquidity when corporations invest in physical rather than financial assets.

C. PROGRESS PAYMENTS AND THE WORKING CAPITAL ADJUSTMENT

Progress payments are timely (usually monthly), partial reimbursements for costs incurred prior to delivery of a completed product. For major contracts in areas other than construction and shipbuilding, all allowable costs incurred on labor and materials are eligible for progress payments. The percentage of costs that is reimbursed prior to final delivery is called the progress payment rate; all remaining costs are reimbursed at final delivery.

The facilities capital cost of money is eligible for progress payments ([6], section 31.205-10(a)(4)), but the facilities capital markup is not. As is argued later, the prohibition of progress payments on the latter appears to provide an incentive for contractors to substitute labor and materials for facilities capital and equipment. This conclusion follows because all expenditures on labor and materials are eligible for progress payments.

Finally, DoD introduced the working capital adjustment in 1987. This component of profit appears as the last row in Table 1. The exact formula is rather complex but, in general, the working capital adjustment is proportional to the *complement* of the progress payment rate. Evidently, this component is intended to compensate contractors for the

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[4] This rate is computed by the Secretary of the Treasury in accordance with 50 *United States Code* App. 1215(b)(2).

interest burden of financing the portion of costs that are *not* promptly reimbursed through progress payments.

Rogerson ([15], Appendix D) has shown that the working capital adjustment used by DoD does not fully compensate contractors for the interest burden. If the cost stream is relatively constant over the life of the project, the working capital adjustment compensates for only a fraction of the interest burden equal to 1.0 - (0.7/T), where T denotes project duration in years. In any event, the working capital adjustment plays a minor role in the empirical work reported here, because it was not introduced until the final year of our sample period.

In light of the preceding discussion, several hypotheses were formulated relating changes in the markup and progress payment rates to changes in the level of investment in facilities capital and equipment. These hypotheses are detailed in the next chapter.

III. HYPOTHESES

A. PROGRESS PAYMENT RATE

Table 2 gives the history of the progress payment rate over our sample period. These are the rates that applied to major contracts in areas other than construction and shipbuilding. The progress payment rate has moved both erratically and non-monotonically over the period. This erractic behavior is mostly the result of varying degrees of political pressure to either raise or lower the rate. For example, the report of the President's Private Sector Survey on Cost Control (known as the "Grace Commission") [14] and subsequent reviews by the Congressional Budget Office and the General Accounting Office concluded that firms in the defense industry were earning "excessive" profits. The resulting political pressures led to the 1985 decrease in the progress payment rate from 90 percent to 80 percent.

Table 2. History of Progress Payment Rate

Policy Regime	Progress Payment Rate
1968-1980	80%
1981	85%
1982-1984	90%
1985	80%
1986-1987	75%

Table 3 reports the working capital burden imposed on contractors by a progress payment rate that falls short of 100 percent. If one dollar is expended in the current period, the "direct" cost is clearly one dollar. However, the contractor also bears an "indirect" or finance cost if the dollar is not fully reimbursed during the current period.

To illustrate the computation of total (direct plus indirect) cost, we assumed an interest rate of $r = .10$ per year. The factor d in Table 3 measures the number of years that full reimbursement is delayed. That is, the contractor receives an immediate, partial reimbusement in the amount p, the progress payment rate. However, the contractor must bear the interest costs of financing the remainder, $1 - p$, for the next d periods. Reimbursement for the remainder occurs in period $d + 1$. The total cost of the one-dollar expenditure is the direct cost of one dollar, plus the indirect cost given by the discounted sum of the interest payments.

Table 3. Sample Calculation of Working Capital Burden

Progress Payment Rate	Duration of Interest Costs			
	d=1	d=2	d=3	d=4
0.0	1.17	1.25	1.32	1.38
0.1	1.16	1.22	1.29	1.34
0.2	1.14	1.20	1.25	1.30
0.3	1.12	1.17	1.22	1.27
0.4	1.10	1.15	1.19	1.23
0.5	1.09	1.12	1.16	1.19
0.6	1.07	1.10	1.13	1.15
0.7	1.05	1.07	1.10	1.11
0.8	1.03	1.05	1.06	1.08
0.9	1.02	1.02	1.03	1.04
1.0	1.00	1.00	1.00	1.00

Equivalently, the indirect cost may be computed as the discounted value of the one-dollar expenditure, \$1, minus the discounted value of the progress payment, \$p, minus the discounted value of the settlement at project completion $\$(1 - p)/(1 + r)^{d+1}$. Hence, the indirect cost is equal to $\$(1 - p)[1 - (1 + r)^{-(d+1)}]$. This formula was used, with an interest rate of $r = .10$, to compute the total cost figures found in Table 3.

For example, a one-dollar expenditure made three years prior to project completion has a total cost of \$1.06 if the progress payment rate is .80, and a total cost of \$1.03 if the progress payment rate is increased to .90.

Recall that while all allowable costs incurred on labor and materials are eligible for progress payments, the facilities capital markup is not. Continuing our numerical example, the total cost of a one-dollar expenditure on facilities capital is \$1.32 (i.e., the effective progress payment rate is zero), independent of the progress payment rate that applies to labor and materials. Therefore, an increase in the progress payment rate from .80 to .90 serves to *increase* the relative price of facilities capital from 1.25 (1.32/1.06) to 1.28 (1.32/1.03).

In general, an increase in the progress payment rate leads to "faster" reimbursement of expenditures on labor and materials, but has no such effect on facilities capital. Hence, we hypothesize that when nominal input prices are held constant, the capital/labor ratio is *inversely* related to the progress payment rate.

B. MARKUP RATE

As indicated in Table 4, the facilities capital markup rate[5] was modified four times over our sample period: 1977, 1980, 1986, and 1987. One of the stated reasons for the modification was to encourage more investment in facilities capital. As noted by Osband ([13], p. 2):

> One long-standing complaint against DoD profit policy is that it discourages facilities investment in favor of flow-through (circulating) expenditures. The criticism is certainly valid pre-1976, for until that time defense contractors received no profit recognition for facilities capital (fixed assets) other than through depreciation. But in recent years nominal facilities capital markups have increased dramatically, while markups on circulating costs have decreased. Whether the markups have shifted enough to correct disincentives remains a controversial question.

We hypothesize that the monotonic increase in the markup rate has promoted investment in facilities capital. A weak version of this hypothesis states that the capital stock has increased over our sample period. However, we will test the more stringent hypothesis that the capital stock has grown more rapidly than employment of labor, so that the capital/labor ratio has increased.

Table 4. History of Facilities Capital Markup Rate

	Markup Rate on Equipment Held by Manufacturers		
Policy Regime	Low	Normal	High
<1977	0%	0%	0%
1977-1979	6%	8%	10%
1980-1985	16%	18%	20%
1986	25%	30%	35%
1987	20%	35%	50%

5 The table reports only the markup rate on equipment. Our data set contains the combined net book value of buildings and equipment for four firms, but buildings and equipment are reported separately for only one of the firms. For this firm, equipment comprises over 90 percent of net book value; we suspect that this percentage is comparable for the other three firms. Therefore, our analysis applies the markup rate on equipment to the combined net book value.

IV. DATA

The data were provided by four large aircraft manufacturers, whose identities cannot be revealed due to the proprietary nature of the data. Information was collected not at the corporate level, but specifically at the level of the plants or divisions that produce military aircraft. There are a total of 66 annual data points. The data series end in 1987 for all four firms, and begin in 1970 for two of the firms, 1972 for the third, and 1974 for the fourth.

The data have been adjusted and normalized to account for changes in the organization and accounting systems of the four firms over the sample period. All variables are measured in 1987 dollars, using deflators that will be described in this section. The variables may be grouped into three categories: input and output quantities, input prices, and a measure of product technology.

A. INPUT AND OUTPUT QUANTITIES

The capital variable, K, is the net book value as supplied by the individual contractors. The producer price index for capital equipment was used to convert the data to 1987 dollars. The labor variable, L, is total employment less those workers in the "occupancy" overhead pool who performed maintenance on facilities and equipment.[6] The unit of measurement is full-time equivalent man-years.

Measures of the physical output rate, Y, were not available from the individual contractors or the DoD. Instead, we constructed a measure of value-added, defined as total cost minus direct materials, subcontracting, and General and Administrative costs. We were concerned, however, that value-added was in part chosen by the firm in an effort to maximize profit or some similar objective. Use of an "endogenous" variable on the right-hand side of a regression leads to biased estimates. To avoid this bias, we adopted a conservative approach and replaced value-added with an instrumental variable.

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6 The workers who performed maintenance on facilities and equipment were not included because they are part of the cost of owning capital. They were included in the computation of the price of capital, discussed later in this chapter.

Clearly, current activity in a plant is related to aircraft that will be delivered in the current year or in the next several years. Therefore, our instrumental variable is a prediction of current activity based on current deliveries and deliveries in the next two years. The two-year horizon was selected because it was consistent with known aircraft production profiles. Finally, the prediction was obtained from a regression containing a first-order autocorrelation correction.

B. INPUT PRICES

Our analysis required data on the prices of the productive factors: capital, labor, and materials. We view the price of capital as the annual dollar cost per dollar of capital stock:

$$PK = [(\text{Depreciation} + \text{Utilities} + \text{Taxes} + \text{Maintenance})/\text{Net Book Value}] + \text{Normal Rate-of-Return.} \quad (1)$$

All of the components except the normal rate-of-return were supplied by the contractors. The normal rate-of-return is measured by Moody's Aaa corporate bond rate ([7], p. 390). The bond rate, which is expressed nominal terms, was deflated using the GNP implicit price deflator ([7], p. 312). The maintenance component in Equation (1) represents the labor cost of those workers who performed maintenance on facilities and equipment.

The price of labor, PL, is the average annual cost (wages and fringe benefits) of all labor in the plant, except that labor used in the maintenance cost computation in Equation (1). The price of labor was deflated using the Consumer Price Index ([7], p. 373). For the price of materials, PM, we used the aircraft materials price index (SIC 3721).[7]

C. TECHNOLOGY MEASURE

Product technology in the aerospace industry has been changing over time. To control for the effects of changing technology, a technology variable was constructed for inclusion in the regression equations. Company delivery schedules were examined, and data were collected on the types of aircraft under construction in each plant in each year. For each type of aircraft, the following index was computed:[8]

$$T_i = \left(\frac{1}{A}\right)\left(\frac{\text{EMW-ENW}}{\text{STW}}\right) \quad (2)$$

---

7 The use of an index to measure input price trends follows the precedent set by Evans and Heckman [8].

8 The index was suggested by Bruce R. Harmon, and the data necessary for its construction were taken from his study on aircraft development costs [10].

for i = 1, 2, . . . , J, where

A = percent aircraft aluminium content

EMW = aircraft empty weight[9]

STW = aircraft structure weight[10]

ENW = aircraft engine weight

J = the number of aircraft types in the contractor's plant in a given year.

The technology index for each plant in each year is a linear combination of the relevant values computed in Equation (2). The weights for the linear combinations W_i are proportional to the total number of each type of aircraft in the contractor's plant in each year. Therefore, the index for a given contractor in a given year is the following linear combination:

$$TECH = \sum_{i=1}^{J} W_i \, T_i . \qquad (3)$$

This index attributes higher technology to aircraft with a lower aluminum content, and a correspondingly higher content of advanced materials. The index also attributes higher technology to aircraft with greater "density," i.e., a higher percentage of non-engine (e.g., avionics) weight. Our index is preferable to using a uniform time trend for all firms, because the latter would ignore aircraft type.

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9 Aircraft empty weight is the total weight of the aircraft less the weight of fuels, crew, missiles, ammunition, and lubricants.

10 Structure weight is the empty weight less the weight of wheels, brakes, tires, tubes, engines, rubber or nylon fuel cells, starters, propellers, auxillary power plant, instruments, batteries, electrical power supply, avionics, turrets, power-operated mounts, air conditioning, anti-icing units, pressure units, cameras, and optical viewfinders.

V. EMPIRICAL FINDINGS

A. PROGRESS PAYMENT RATE

To test the hypothesis on the progress payment rate—when nominal input prices are held constant, the capital/labor ratio is inversely related to the progress payment rate—a regression analysis was performed. The population model is:

$$\begin{aligned} \ln (K_t/L_t) = \beta_0 + \beta_1 \ln (PL_t) + \beta_2 \ln (PK_t) + \beta_3 \ln (PM_t) \\ + \beta_4\, TECH_t + \beta_5\, PPR_t + \beta_6 \ln (\hat{Y}_t) \\ + \beta_7\, D1_t + \beta_8\, D2_t + \beta_9\, D3_t + \varepsilon_t \end{aligned} \quad (4)$$

The variables K_t, L_t, PL_t, PK_t, PM_t, and $TECH_t$ are the capital, labor, factor price, and technology variables described in Chapter IV. The progress payment rate, PPR_t, is a continuous variable based on the values shown in Table 2; for example, if t=1981, PPR_t= 0.85. The variable $\hat{Y}_t$ is the output instrumental variable, and the variables $D1_t$, $D2_t$, and $D3_t$ are firm-specific dummy variables that were used in pooling the time-series for the four firms. We included the output variable because to do otherwise would impose the restriction that the capital/labor ratio is independent of the level of output. We had no basis for this restriction and, in fact, it is rejected in our data set. Finally, a first-order autocorrelation structure is assumed for ε_t: $\varepsilon_t = \rho\varepsilon_{t-1} + V_t$, where V_t is distributed independent normal, N $(0, \sigma_v^2)$.

The regression results are shown in Table 5. The regression fits the data quite well, with an R-squared of .988. In addition, the coefficients on labor price and capital price have the correct signs and are statistically significant. The output variable is significantly different from zero, justifying our inclusion of this variable in the equation. However, the variable of primary interest, the progress payment rate, is not statistically significant. We found no evidence that the capital/labor ratio is inversely related to the progress payment rate.

Table 5. Regression Results for Model with Progress Payment Rate [Equation (4)]

Variable	Coefficient	Standard Error
Intercept	4.552	1.940
Labor Price	.761	.248
Capital Price	-1.067	.100
Material Price	1.486	.136
Technology	.014	.004
Progress Payment Rate	.206	.273
Predicted Output	-.395	.120
D1	-.898	.106
D2	.353	.148
D3	-.446	.097
Rho	.499	.134
n = 66,	R-squared = .988	

Progress payments of less than 100 percent seem to act as a "tax" on contractors, who must bear financing costs until project completion. However, our results suggest that incomplete progress payments act as a "lump-sum" tax, reducing profits but not affecting the mix of capital, labor, and materials selected by the contractor. Moreover, the working capital adjustment, introduced in 1987, compensates the contractor for most of the financing costs. Therefore, the tax on contractors has essentially been repealed.

Note that we did not restrict the capital/labor ratio to be homogeneous of degree zero in the input prices. If our four firms were minimizing cost, then demand for each input would be homogeneous of degree zero, and so would be the ratio of any two demand functions. Under these conditions, the sum of the demand elasticities would be zero,[11] $\beta_1+\beta_2+\beta_3=0$.

We rejected the homogeneity condition with a t-statistic of 4.34. Evidently, the objectives of our four firms are not simply to minimize cost. There are many alternative

[11] See Chambers ([2], p. 65).

objectives which, when rationally pursued, do not lead to homogeneous demand functions.[12] This matter is explored further in a forthcoming paper [9].

B. MARKUP RATE

To test the hypothesis on the markup rate—increases in the markup rate promote investment in facilities capital—two additional regression analyses were performed. The population model for the first regression is:

$$\begin{aligned} \ln (K_t/L_t) = {} & \beta_0 + \beta_1 \ln (PL_t) + \beta_2 \ln (PK_t) + \beta_3 \ln (PM_t) \\ & + \beta_4 \, TECH_t + \beta_5 \, MUR_t + \beta_6 \ln (\hat{Y}_t) \\ & + \beta_7 \, D1_t + \beta_8 \, D2_t + \beta_9 \, D3_t + \varepsilon_t \end{aligned} \tag{5}$$

and the model for the second regression is:

$$\begin{aligned} \ln (K_t/L_t) = {} & \beta_0 + \beta_1 \ln (PL_t) + \beta_2 \ln (PK_t) + \beta_3 \ln (PM_t) \\ & + \beta_4 \, TECH_t + \beta_5 \ln (\hat{Y}_t) + \beta_6 \, MU1_t \\ & + \beta_7 \, MU2_t + \beta_8 \, MU3_t + \beta_9 \, MU4_t + \beta_{10} \, D1_t \\ & + \beta_{11} \, D2_t + \beta_{12} \, D3_t + \varepsilon_t \end{aligned} \tag{6}$$

In addition to the variables introduced in Equation (4), the remaining variables are related to the facilities capital markup. In Equation (5), MUR_t is a continuous variable that assigns the normal markup rate to each time period. From Table 4, if $t < 1977$, $MUR_t = 0$; if $1977 \le t \le 1979$, $MUR_t = .08$; etc. In Equation (6), $MU1_t$, $MU2_t$, $MU3_t$, and $MU4_t$ are four dummy variables that define the different markup policy regimes; i.e.,

$$MUi_t = \begin{cases} 1 & \text{for those years where policy regime } i = 1, 2, 3, 4 \text{ applies;} \\ 0 & \text{otherwise.} \end{cases}$$

The omitted or "base" period, for which we did not define a dummy variable, is the period $t < 1977$.

[12] Consider, for example, the Averch-Johnson model of the regulated firm. In this model, the effect of the price of labor on demand for labor and capital is generally non-zero. However, Bailey ([1], p. 129), Cowing ([3], p. 221) and McNicol ([11], p. 438) have shown that the effect of the price of capital on demand for labor and capital is zero. Hence, neither the demands nor their ratio may be expressed solely in terms of relative prices.

Equation (6) provides a more stringent test of our hypothesis than does Equation (5). Recall that the markup rate increased monotonically over our sample period. If our hypothesis is correct, then the capital/labor ratio should have increased monotonically as well. Equation (6) is a step-function, and each successive step should be at a higher level. Hence the coefficients on the dummy variables should not only be positive, but should form an increasing sequence.

Equation (5) is not as stringent. Even if one of the dummy variables in equation (6) were out of sequence (i.e., an increase in the markup rate between two adjacent periods led to a lower capital/labor ratio), the overall effect might still be a positive coefficient on the markup rate in equation (5).

The parameter estimates for Equations (5) and (6) are presented in Tables 6 and 7, respectively. The estimates in both cases agree with *a priori* expectations and, in particular, the estimated markup rate coefficients support the stated hypothesis. In Table 6, the coefficient on markup rate is positive and significant. The markup coefficient suggest that for a one percentage-point increase in the markup rate, the capital/labor ratio rises by 0.782 percent. In Table 7, the coefficients on MUi_t are positive, statistically significant, and strictly increasing. That is, a strictly increasing markup rate has been associated with a strictly increasing capital/labor ratio.

The discussion so far has focused on the four firms. When the impact of the markup rate is viewed from an industry level, an interesting question arises. Can we estimate, for the defense aircraft industry as a whole, how much net investment may be attributed to the markup policy? To answer this question, the results presented in Table 6 were used to simulate the impact this policy has had on the net capital stock of defense aircraft industry, from the inception of policy in 1977 through 1987. The results of the simulation suggests that, since 1977, approximately $13 billion (FY87 dollars) has been added to the net capital stock of the industry due to the markup policy. This figure represents a 4-percent increase in the net capital stock .

Table 6. Regression Results for Model with Continuous Markup Rate Variable [Equation (5)]

Variable	Coefficient	Standard Error
Intercept	4.070	1.890
Labor Price	.738	.239
Capital Price	-.962	.105
Material Price	.969	.201
Technology	.013	.004
Markup Rate	.782	.293
Predicted Output	-.341	.115
D1	-.992	.112
D2	.261	.144
D3	-.468	.092
Rho	.566	.132
n = 66,	R-squared = .989	

Table 7. Regression Results for Model with Markup Rate Dummy Variables [Equation (6)]

Variable	Coefficient	Standard Error
Intercept	4.569	2.043
Labor Price	.734	.258
Capital Price	-.944	.110
Material Price	1.096	.205
Technology	.013	.004
Predicted Output	-.375	.120
MU1	.043	.049
MU2	.150	.071
MU3	.166	.107
MU4	.259	.106
D1	-1.016	.125
D2	.257	.147
D3	-.460	.094
Rho	.522	.134
n = 66,	R-squared = .989	

VI. CONCLUSIONS

This paper has addressed the effects of two DoD policies on the degree of capital investment among aircraft manufacturers. First, DoD offers progress payments to reimburse the majority of expenditures on labor and materials. If the progress payment rate increases, there should be an incentive for the contractor to substitute labor and materials for capital in production.

We found no evidence of this effect in our data. Progress payments of less than 100 percent seem to act as a lump-sum tax on contractors, reducing profits but not affecting the mix of capital, labor, and materials. However, the working capital adjustment, introduced in 1987, compensates the contractor for most of the financing costs associated with partial progress payments. Therefore, the tax on contractors has essentially been repealed.

Second, we tested whether historical increases in the facilities capital markup rate have been translated into corresponding increases in the degree of capital investment. In this instance, we did find strong support for our hypothesis.

Recall that the facilities capital markup was introduced in response to an internal DoD study performed in 1976. That study found that, in 1975, the ratio of facilities capital to sales was 20 percent in the commercial manufacturing sector, but only 9 percent in the defense sector. Coincidentally, the average capital/sales ratio among our four firms was also 9 percent in 1975.

As Table 8 indicates, the capital/sales ratio in the commercial sector increased only slightly, to 23 percent in 1983 (the last year of the DFAIR data). However, the capital/sales ratio among our four firms increased to 17 percent in 1983, and continued increasing to 22 percent in 1987 (the last year of our data). Apparently, the generous DoD markup policies have had the desired effect, and have encouraged the defense sector to close the gap with the commercial sector.

Table 8. Comparison of Capital/Sales Ratios

Year	DFAIR's Durable Goods Manufacturers[a]	IDA's Four Aircraft Manufacturers
1975	20	9
1980	21	15
1983	23	17
1987	NA	22

[a] From [5], Exhibit 4, p. VI-9. Note that the DFAIR study covered the period ending in 1983.

REFERENCES

[1] Bailey, Elizabeth E. *Economic Theory of Regulatory Constraint.* Lexington, Mass.: Lexington Books, 1973.

[2] Chambers, Robert. *Applied Production Analysis: A Dual Approach.* Cambridge: Cambridge University Press, 1988.

[3] Cowing, Thomas G. "The Effectiveness of Rate-of-Return Regulation: An Empirical Test Using Profit Functions." *Production Economics: A Dual Approach to Theory and Applications*, edited by Melvyn Fuss and Daniel McFadden. Amsterdam: North-Holland, 1978.

[4] Department of Defense. *Profit '76 Summary Report.* Office of the Assistant Secretary of Defense (Installations and Logistics), December 1976.

[5] Department of Defense. *Defense Financial and Investment Review (DFAIR).* Washington, D.C: U.S. Government Printing Office, June 1985.

[6] Department of Defense. *Federal Acquisition Regulation* (*FAR*): *Department of Defense, General Services Administration, and National Aeronatics and Space Administration.* Reprinted by Commercial Clearing House, Inc., Chicago, Illinois, April 1984.

[7] *Economic Report of the President.* Washington, D.C: U.S. Government Printing Office, 1989.

[8] Evans, David S., and James J. Heckman. "Multiproduct Cost Function Estimates and Natural Monopoly Tests for the Bell System." In *Breaking up Bell*, edited by David S. Evans. Amsterdam: North-Holland, 1982.

[9] Goldberg, Matthew S., Thomas P. Frazier, and Thomas R. Gulledge. *A Regulatory Interpretation of DoD Profit Policy.* Institute for Defense Analyses, P-2407, forthcoming.

[10] Harmon, Bruce R., et al. *Military Tactical Aircraft Development Costs, Volume I: Summary Report.* Institute for Defense Analyses, R-339, September 1988.

[11] McNichol, David L. "The Comparative Statics Properties of the Theory of the Regulated Firm." *Bell Journal of Economics and Management Science*, Vol. 4, No. 2, (Autumn 1973), pp. 428-453.

[12] Myers, Myron, et al. *Facilities Capital as a Factor in Contract Pricing.* Logistics Management Institute, May 1985.

[13] Osband, Kent. *Target Profitability Under DoD Profit Policy*, The RAND Corporation, WD-4282-PA&E, February 1989.

[14] President's Private Sector Survey on Cost Control (Grace Commission). *Report on Financial Asset Management.* Washington, D.C: U.S. Government Printing Office, September 1983.

[15] Rogerson, William P. *An Economic Framework for Analyzing DoD Profit Policy*, Working Draft, Northwestern University, April 1989.